System Considerations with High Resolution Detectors

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Application Note

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System Considerations with High Resolution Detectors

This application note describes some commonly encountered problems in achieving optimal detector resolution performance in routine use rather than under ideal laboratory conditions and proposes some recommendations on how to attain the best performance.

System Design Considerations

High resolution spectroscopy systems require several connections involving the preamp, bias supply, and spectroscopy amplifier. Under normal operating conditions this does not present a problem, and optimal performance is achieved.

However, in some applications these interconnections are unusual in terms of environment, length, or routing. Under such conditions, systems are susceptible to oscillations or noise due to ground loops or to EMI (electromagnetic interference) from sources such as raster displays, power supplies, computers, etc. This interference will degrade the performance of most high resolution detector systems.

The LB1500 Series Accessories

The *LB1500 Series Loop-Buster accessories* starting on page 6 minimize these problems without affecting cable lengths, cable routing, or system configuration.

Amplifier Shaping

The shaping time constant sets the amplifier's pulse processing time and frequency response. The proper choice is usually a compromise between detector performance at low and high count rates. For example, Ge detectors usually provides best resolution performance with longer shaping selections, but at very high count rates pile-up effects and degradation of throughput can be reduced with faster shaping selections.

The optimum time constant depends on detector characteristics (size, configuration, collection characteristics) and the incoming count rate. Table 1 lists optimum time constant ranges for Gaussian shaping and common detectors under normal operating conditions. For DSP (Digital Signal Processors) Spectroscopy Amplifiers please see the recommended shaping times (Rise Time and Flat Top) and tradeoffs in the respective user manual.

Table 1 Detector Time Constants

Scintillation [NaI(Tl)]	0.5 – 1.5 µs
Gas Proportional Counters	0.5 – 2.0 µs
Silicon Surface-Barrier (SSB)	0.5 µs
Passivated Implanted Planar Silicon (PIPS)	0.5 µs– 1.0 µs
Lithium Drifted Silicon [Si(Li)]	8.0 – 24.0 µs
Low Energy Germanium	8.0 – 24.0 µs
Germanium	4.0 – 6.0 µs

Some spectroscopy amplifiers are specified by pulse width or time to peak. The equivalent shaping time constant for a unipolar amp, with Gaussian shaping, is approximately equal to Time-to-Peak divided by 2.2.

Amplifier Noise

Amplifier noise is random in nature and is summed in quadrature (RSS) with the noise from the detector and the preamplifier. The amplifier's gain is selected so that the energy range of interest matches the ADC's full scale range. The amplifier is carefully designed and optimized to minimize noise contribution and resolution degradation.

Baseline Restorer

For best signal to noise performance, a direct coupled amplifier with unipolar shaping would be the best theoretical solution, but is not practical because of offset voltages in the preamplifier and amplifier. Therefore, an AC coupled amplifier is required for DC stability. But in an ac coupled amplifier, count rate changes can cause shifts in the baseline unless a bipolar pulse shaping or a baseline restoration (for unipolar shaping) is used.

Bipolar shaping eliminates the effects of DC offset but, has worse signal-to-noise ratio and count rate performance compared to unipolar shaping which results in degraded resolution.

A Baseline Restorer removes the fluctuations for the unipolar output by monitoring the baseline and provides active correction to compensate for baseline shift (due to count rate variations) and temperature drift.

In most CANBERRA amplifiers, an Auto Threshold circuit tracks the baseline of the unipolar output and gates the restorer off for detector events that exceed the threshold which minimizes resolution degradation (peak broadening) and peak shift over a wide range of count rates.

ADC Conversion Gain

To calculate the centroid and Full Width at Half Maximum (FWHM) of a spectral peak, at least 20 channels are required in the peak to obtain accurate results. If the peak has fewer channels, the uncertainty due to poor statistics may degrade the peak FWHM measurement.

The ADC Conversion Gain determines the number of elements (channels) that the input signal is divided into, which affects the number of channels a spectral peak is resolved into. For a scintillation detector, a Conversion Gain of 256 or 512 is sufficient to resolve expected peaks. Higher ADC Conversion Gain can be used to provide additional channels for increased resolution.

For high resolution Germanium detectors operating over a wide energy range, an ADC Conversion Gain of 8192 and higher is commonly used to adequately determine the peak FWHM. Using lower ADC Conversion Gains, the FWHM calculation can be in error or degraded by 50 to 100 eV because of the granularity of the data points and poor statistics. This can also be reduced by analyzing the spectral data using a peak fitting application.

System Setup Configuration

The previous factors can be analyzed prior to assembling the proper system for the intended application and are important considerations for the system design. The following are some practical points that permit a system to perform to its potential.

Pole/Zeroing

The pole/zero (P/Z) adjustment matches the amplifier to the preamplifier’s tail pulse output and is extremely critical for good high count rate performance. When set properly, the effects of closely spaced pulses (pile up) are minimized. This adjustment compensates for the exponential decay time constant of the preamplifier pulse. The P/Z must be adjusted if the Amplifier Shaping is changed, but it will not change with Amplifier Gain.

For precise and optimum setting of the P/Z, an oscilloscope vertical scale of 50 mV/cm, or less, should be used. However, most scopes will overload for a 10 volt input signal and a low vertical scale setting. As a result the scope can distort the signal’s recovery to the baseline and the P/Z will be incorrectly adjusted, resulting in a loss of resolution at high count rates. To prevent overloading the scope, CANBERRA recommends using the **Model LB1502 Schottky Clamp Box** between the amplifier’s output and the scope’s input.

Note that the Models 2025 and 2026 Spectroscopy Amplifiers have a built-in Schottky clamping circuit.

Amplifier Oscillations

If the cable connecting the front panel output of the amplifier to the ADC exceeds 3 m (10 ft) in length, oscillations can occur. This is caused by the cable capacitance loading the high bandwidth output of the Shaping amplifier.

Most CANBERRA Amplifiers have a rear panel output which has a 93 ohm output impedance to minimize the potential for oscillations. Most amplifiers also have internal jumpers that can add a 93 ohm resistor in series with the front panel output (source termination). In some cases it may be necessary to use the low impedance amplifier output. For this case, adding a terminating resistance at the far end of the cable (load termination) can also minimize the potential for oscillation. Source or load terminating the output does not attenuate the signal when using the low output impedance selection. If both source and load termination is used, the signal amplitude will be attenuated by 50%. The coax cable should be chosen so that its' characteristic impedance matches the output impedance of the Preamplifier or Amplifier output. RG62/U coax cable has a 93 ohm characteristic impedance. This cable should also be used when the output impedance is set for 0 ohms and short cable lengths. For longer cable lengths, one should "source" or "load" terminate as described above.

Vibration and Noise

Vibration transmitted to the detector and cryostat can be through the floor or mounting, as well as direct audio coupling through the air. Vibration isolators in the mounting and sound absorbing covers around the detector can reduce this problem. Shortening the amplifier shaping time constant may improve spectrometer performance in a noisy environment.

Radio Frequency Interference (RFI)

In close proximity, a radio station can sometimes be picked up by a detector. Grounding the preamplifier or cryostat may help, but this can cause ground loops, resulting in 50 or 60 Hz noise. Refer to the following Grounding subsection.

Analyzer Interference

If the detector is located within a few feet of the MCA, it can receive Electro-Magnetic Interference (EMI). In older analyzers this can be from the ferrite cores that were used as memory elements. On MCAs with raster displays, the display has yoke and flyback transformers that generate large magnetic fields.

The cables connecting the detector, preamplifier and amplifier must be kept away from EMI emitting devices; definitely do not run the cables in front of the MCA or computer display. Some further techniques in minimizing the interference in extraordinary circumstances are covered in the following Grounding subsection.

Large Distances between Detector and Electronics

Another configuration to be considered is what to do when the detector is hundreds of feet away from the MCA. It's usually not practical to separate the ADC from the MCA. Therefore the amplifier and HVPS are kept near the detector using short cables. The amplifier output (high level signal) is connected to the ADC/MCA input, which is further away, using the longer cable. Because the amplifier input signal is high level any noise pickup will have a smaller impact on signal-to-noise ratio.

Note: When using long cables on the amplifier output it may be necessary to use the 93 ohm output impedance to prevent oscillation due to the higher cable capacitance.

Grounding

Grounding problems often cause poor performance from a detector. On analog systems (NIM), best performance is generally obtained when the amplifier, ADC and high voltage power supply (HVPS) are installed in the same bin, with preamp power coming from the amplifier.

Degradation caused by preamp power circuit ground loops can be minimized by the **Model LB1501 Ground Loop Eliminator (GLE) Preamp Power Cable**, which has a diode-interrupted ground.

If noise coupling from adjacent NIM modules is suspected try separating the amplifier by several slots from the ADC and bias Supply in the NIM Bin.

If EMI noise pickup is suspected in the ground loop associated with the Preamp output to Amplifier input connection try connecting the **Model LB1500 Cable Transformer** in series with the with the preamp to amplifier coax cable. The LB1500 provides a means to minimize noise signals induced in the cable. If the ground loop, associated with the Preamp to HVPS connections is suspected try inserting the **Model 1503 Bias Isolation Box** in the HV coax cable connection between the Preamp and HVPS. The LB1503 Bias Isolation Box provides resistive isolation, in the ground circuit, between the Preamp and HVPS. Note: ground isolation is built in on most CANBERRA preamps and HV power supplies.

Ground loops can also be created when a system has multiple connections to the AC mains, the associated grounds can make the system susceptible to noise pickup and performance degradation. Ground loops, when present, allow EMI noise, conducted noise and/or power line common mode noise to couple into the system grounding. EMI noise sources include electro-magnetic noise produced by MCA and computer AC/DC power adapters, switching power supplies, transformers, motors, monitors, or radio stations to name a few. Conducted noise is generally produced by common mode noise associated with the AC mains. If the system includes sensitive instruments and sensors such as Germanium detectors, preamps, signal processors and MCAs, noise currents can circulate in the ground conductors which create a potential difference or noise voltage between the detector and front end electronics. This noise voltage adds to the detector/preamp signal resulting in degraded resolution. In systems utilizing an electrically cooled detector (which are grounded via the AC mains ground), the cooler should be powered via the LB1504 Ground Isolation Box to reduce the effects of noise

currents flowing in the associated system (detector/preamp and Amp/ADC/MCA) ground connections.

USB Isolation

In systems utilizing the Canberra iPA preamplifier (or other equipment) with USB communication connections, it is possible that a ground loop may be formed through the AC mains of the spectroscopy system and host computer via the USB cable. If system resolution degradation is believed to be attributed to this ground loop mode, try connecting an in-line USB isolator between the preamplifier (or other equipment) and the host computer USB ports. The following USB isolators support 2kV isolation at 12Mbps (Full Speed USB 1.1), and have been evaluated by Canberra for use with Canberra spectroscopy systems:

In the US: BlackBox SP386A

In the EU: B&B Electronics UH401-2KV

Loop-Buster Accessories

These Loop-Buster accessories are designed to minimize the interference and ground-loop problems which can be encountered in some system configurations. See Figure 7 and Figure 8 for typical connections of the loop buster discussions that follow.

Model 1500 Cable Transformer (CT)

The LB1500 Cable Transformer (Figure 1) is a 93 ohm coax cable with built in ferrite core. Connect it between the preamplifier output and the amplifier input to reduce high frequency interference.

Note: The LB1500’s female BNC connector must not be allowed to touch ground.

Figure 1 LB1500 Cable Transformer

Model LB1501 Preamp Power Cable (GLE)

The LB1501 Ground Loop Eliminator Preamp Power Cable (GLE) (Figure 2) has a diode-interrupted ground to eliminate ground loops. Use this cable in place of the C1402 Preamp Power Cable supplied with the preamplifier.

Figure 2 LB1501 Preamp Power Cable

Model LB1502 Schottky Clamp Box

Prevents oscilloscope overload when using high vertical sensitivity settings for precise pole/zero adjustments. Not required with amplifiers that have a built-in limiting circuit. See Figure 3 and Figure 4.

Figure 3 LB1502 Schottky Clamp Box - Front View

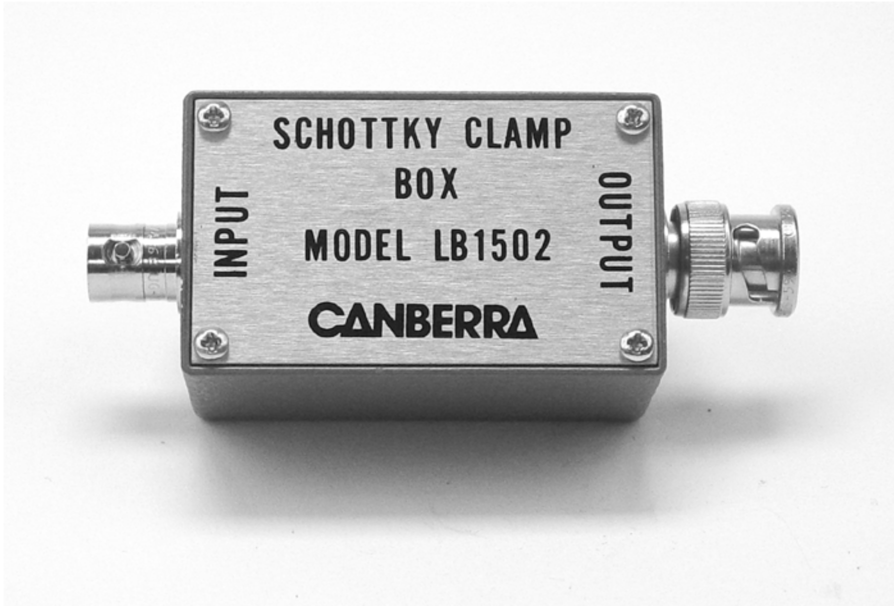

Figure 4 LB1502 Schottky Clamp Box - Back View

Model LB1503 Bias Isolation Box

The LB1503 Bias Isolation Box (Figure 5) provides resistive isolation in the ground circuit between high voltage power supply and preamp to reduce ground-loop induced noise. Note: ground isolation is built in on most CANBERRA preamps and HV power supplies.

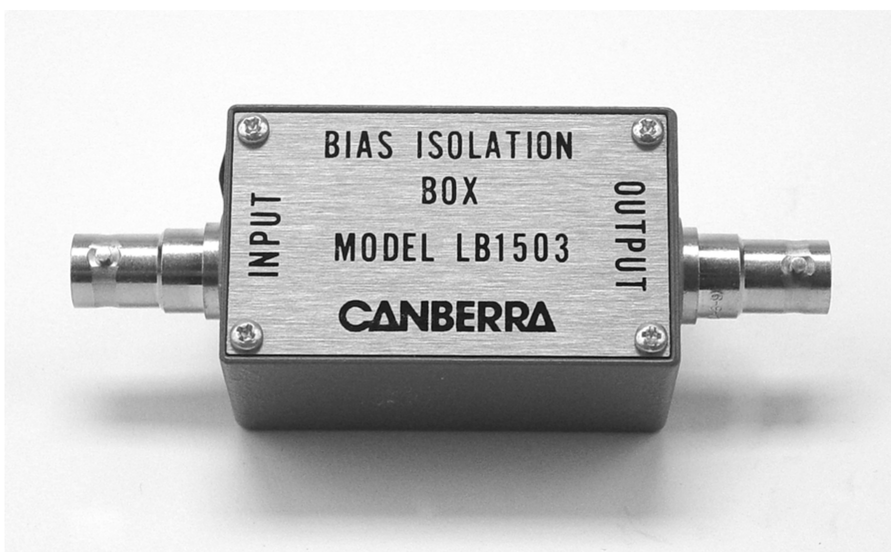

Figure 5 LB1503 Bias Isolation Box

Model LB1504 Ground Isolation Box

The LB1504 Ground Isolation Box (Figure 6) is used to mitigate performance degradation that might result from ground loops or associated EMI noise pickup.

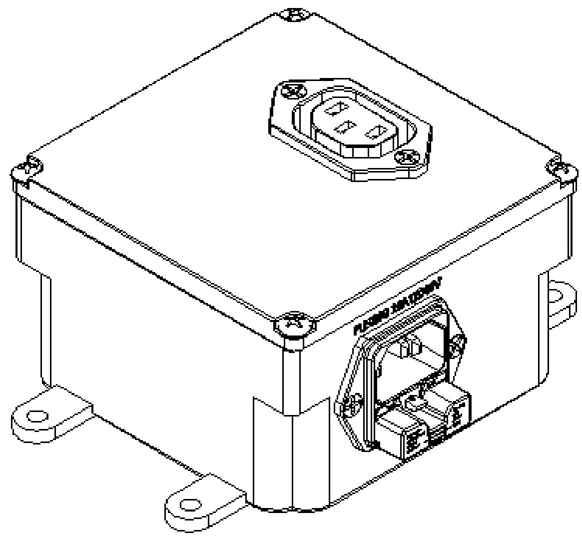

Figure 6 LB1504 Ground Isolation Box

The Ground Isolation Box includes a choke connected between the input and output earth (safety) grounds. Due to the nature of inductance, the input/output ground remains low impedance for DC and low frequencies, so the integrity of the safety ground is maintained. At the higher frequencies associated with noise, the impedance increases making potential ground loops less susceptible to noise coupling and pickup. See Figure 7 for a block diagram showing a typical system connection of the LB1504 Ground Isolation Box. The Ground isolation Box does not correct for common mode noise on the AC mains power. For severe power line noise of this type, an isolation transformer may be required in addition to the LB1504.

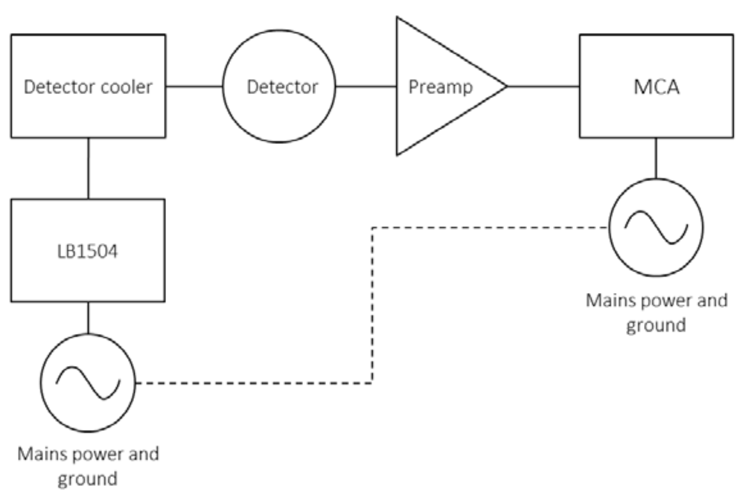

Figure 7 Ground Loop Though the Mains Power Supply

Typical Use of the Loop Buster Accessories

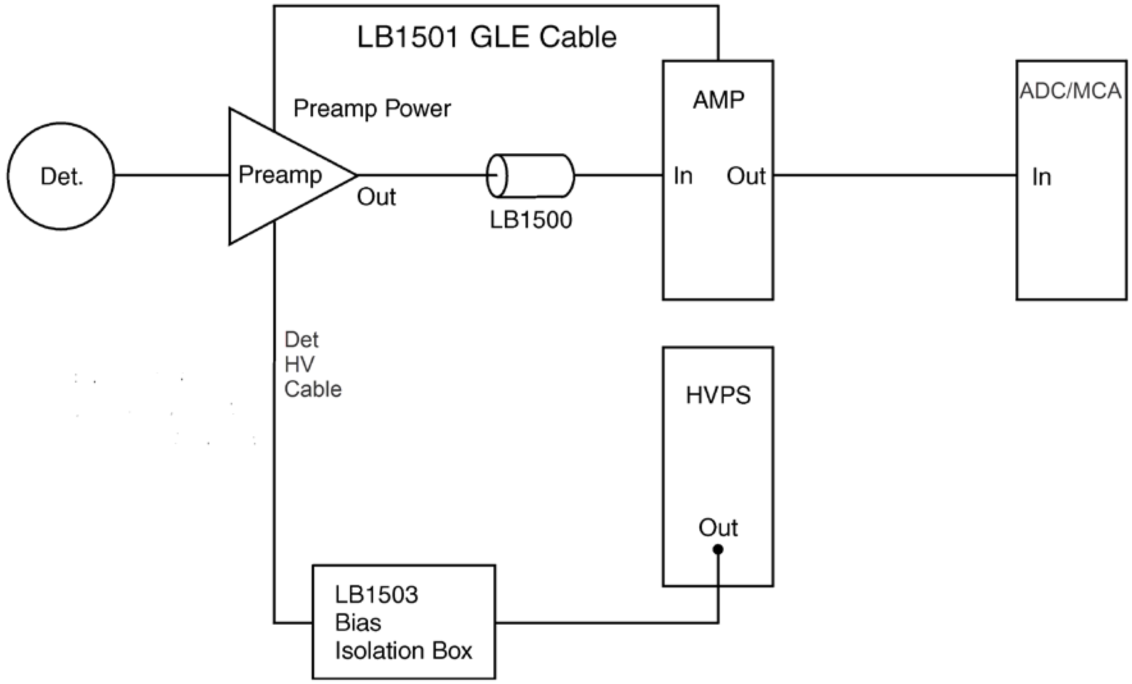

Figure 8 Typical use of loop buster accessories

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